Missouri Department of Natural Resources
Water Protection Program

Total Maximum Daily Load (TMDL)

for

Trace Creek
Madison County, Missouri

Completed: September 27, 2004
Approved: November 15, 2004

Total Maximum Daily Load (TMDL)
For Trace Creek
Pollutant: pH
Phase I[1]

Name: Trace Creek

Location: Near Routes C and CC in southwest
Madison County, Missouri

Hydrologic Unit Code (HUC): 08020202-030003

Water Body Identification Number (WBID): 2850

Missouri Stream Class: Class C stream[2]

Beneficial Uses:
- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption

Size of Impaired Segment: 1.0 mile

Location of Impaired Segment: From SE ¼ Section 29, T32N, R6E (downstream) to NE ¼ Section 29, T32N, R6E (upstream)

Pollutant: pH

Pollutant Source: Natural[3]

TMDL Priority Ranking: Medium

1. Background and Water Quality Problems

Area History:
[4]The first European settlers in the area of Madison County were the explorers and miners LaMotte, Renault and their companions in 1721-23. They did not stay, since they found no silver, but they

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[1] Phase I of a TMDL is the first step to resolving the water quality problems of a creek. It reflects where we are now in our understanding and knowledge of the waterbody's condition and includes further monitoring. Phase II occurs when sufficient data have been collected to either confirm the present assumptions or point to more appropriate methods for resolving the impairment.
[2] Class C streams may cease to flow in dry periods but maintain permanent pools that support aquatic life. See 10 CSR 20-7.031(1)(F)
[3] While the pollutant source is listed as "natural" in the 2002 303(d) list, this document suggests that atmospheric deposition/acid rain is a likely source of acidity in Trace Creek.
[4] Encyclopedia of the History of Missouri. Vol. IV. 1901. Howard Conard, Ed. New York, Louisville and St. Louis. Haldeman, Conard and Company, Proprietors

did discover a shiny, gray mineral [galena] that was lying everywhere, often on the surface of the ground. This turned out to be usable lead ore and the subsequent lead workings established there were named Mine LaMotte. The mine supported a fluctuating, temporary population due to being worked only a few months a year.

Madison County was organized December 14, 1818, and named for the fourth U.S. President, James Madison, who held that office from 1809-1817. The county was reduced to its present size in 1857 when Iron County was cut from it. The first county seat was in St. Michaels. It was moved to Fredericktown a year later, in 1819, and a courthouse was built in 1822. This was torn down in 1899, 77 years later, to make way for a new one. The new courthouse was completed in November 1900, (made of native stone) cost $22,000 and is considered one of the "most substantial and handsome public buildings in southeast Missouri."

Soils and Land Use:
Trace Creek is located in a valley about 18 miles southwest of Fredericktown. Highway CC branches off of Highway C and leads down into this valley. It flows westward through a heavily forested watershed and joins Twelve Mile Creek just before that creek's confluence with the St. Francis River. It (Trace Creek) borders the Rock Pile Mountain Wilderness, with County Road 423 running between them. This provides ready access to the creek and Wilderness alike. In addition, much of the length of the sawmill tributary (discussed below) flows through a block of the Mark Twain National Forest. Years before the European settlers arrived, Native Americans had a trace (trail) that ran along the creek, presumably leading to its present name. Topography in Madison County ranges from valleys to high hills and mountains. Rock Pile Mountain is the highest peak at 575 feet. Soil in the northern part of the county is based on syenite rock and can bear fair crops, but it is more suited for fruit growing. Lumber is one of the chief industries. From the late 1800s to the mid-1900s, several large sawmills were located on upper Trace Creek. As one mill would leave, another would move in[5]. Mining is another important industry with some of the minerals mined being lead, zinc, iron, cobalt, nickel, copper and silver. However, only one long abandoned mine was found to be in the Trace Creek watershed (see Source Analysis – Nonpoint Source Component). The land is primarily in forest/woodlands (96 percent) and grasslands (3 percent). There are no towns in the watershed above the impaired section. More detailed land use information may be found in Appendix A.

The main bottom land soil along upper Trace Creek is Tilk, very gravelly sandy loam with slopes of 1-3 percent. This is a very deep, well-drained soil with moderately rapid permeability that is rarely flooded. Soils on side slopes and uplands is the Clarksville-Sholten complex with 15-45 percent slopes. This complex is very deep and very stony. In more minor amounts along the creek are several very deep silt loams: Secesh (0-3 percent slope), Marquand and Aslinger with slopes of 3-8 percent. Secesh is well drained with moderate permeability while the other two are moderately well drained with moderately slow permeability. A discussion about the possibility of acidity from Tilk soil may be found in the Source Analysis section under Buffering Capacity.

[5] Historical Madison County 1818-1988. Pub. The Heritage and Landmarks Commission and the Madison Historical Society. Josten Printing and Publishing Division. Topeka KS

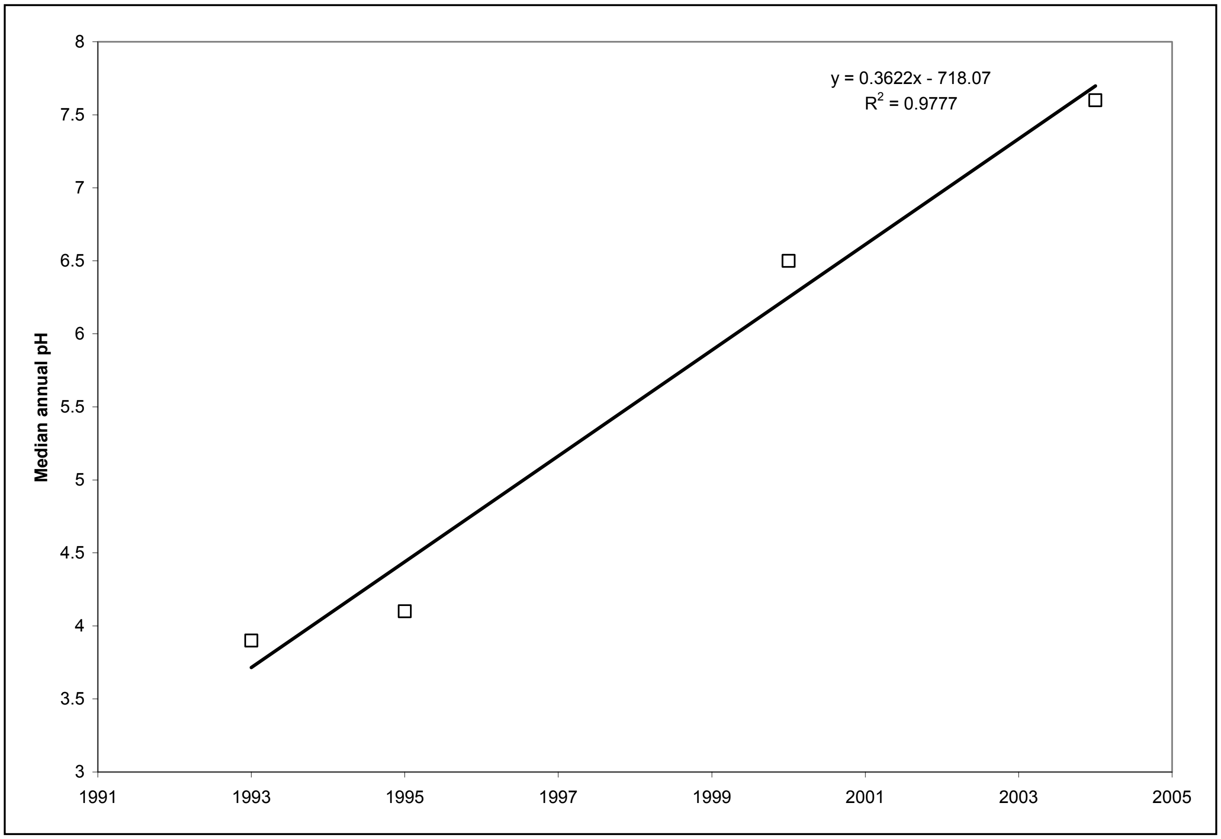
Defining the Problem:
The creek is listed as impaired by low (acidic) pH due to natural causes. Much of the bedrock in the upper portion of the watershed is igneous rock (granite and rhyolite, in this case), which does not neutralize the acidity in rainwater. Rainwater in this area averages a pH of 4.90 SU. Table 1 shows the median pH was 4.64 SU in 2001. Limestone on the other hand, which is abundant in most of Missouri but lacking in this area, is composed of calcium carbonate and is a good buffer. This portion of Trace Creek is often too acidic to meet Missouri Water Quality Standards (WQS), which require the pH of state waters to be between 6.5 and 9.0 SU.

- **Source Analysis: Point Sources**

This acidity problem was aggravated in the early 1990s by a discharge to Trace Creek of leachate[6] from a sawdust pile at Madison County Wood Products. This facility is a sawmill that has a number of piles of sawdust which have been there since the late 1970's. In 1993, one set of samples showed a pH of 3.8 in the tributary to Trace Creek carrying the sawdust pile leachate. The pH was 5.2 in Trace Creek above this tributary and 4.7 one mile below this tributary. Since that time, continued removal of the sawdust material from the site, and exhaustion of the leachate over time has resulted in higher pH readings in the receiving stream (figure 1). Ten sets of water quality measurements were made in 2000 in a special study. Median pH values for these measurements were: pH of 6.5 in the tributary from the sawdust pile, pH of 6.4 in Trace Creek upstream of this tributary and pH of 7.3 in Trace Creek one mile downstream of this tributary. Based on this data (Appendix C), the extent of the impaired area was reduced on the 2002 303(d) list to one mile and the sawdust pile was dropped as a source.

[6] Leachate is the liquid that comes from a mound such as a sawdust pile or landfill. It is the result of rainwater percolating through the pile that removes (leaches) soluble or other constituents from the pile, especially contaminants.

Figure 1: Median annual pH at mouth of tributary from MCWP sawmill



- **Source Analysis: Nonpoint Source Component**

There is no significant agricultural nonpoint source of impairment upstream from the impaired length of Trace Creek. About three percent of the watershed is in pasture. Hay production and pasture management are improbable as significant nonpoint sources of stream acidity.

Mining

There is no indication that any mining activity, past or present, is influencing acidity in Trace Creek. In searching Missouri's mine records, only one mine was located in the Trace Creek watershed above the impaired segment. It is identified as Platina Mine. It was an old surface copper mine and is shown on a map from 1859. A site investigation found the only evidence of past mining activity was some loosened soil and the remnants of a shallow pit. There had recently been substantial rain but there was no evidence of seepage. Additionally, the pH readings in the stream below were not acidic.

Atmospheric Deposition

Atmospheric deposition is the most likely anthropogenic source of stream acidity in Trace Creek. Acid rain in Missouri is not normally considered to be an issue of the same magnitude as it is in the north-eastern United States, where there are no carbonate rocks to buffer it. Normal rain pH is around 5.5 (EPA, 2003; USGS, 1997). However, data from the National Atmospheric Deposition Program (NADP) National Trends Network (NTN) indicate that acid rain is a significant

factor in southeastern Missouri. The following summary statistics are derived from data from the monitoring station at the University of Missouri Forestry Camp, located about 36 miles south-southeast of Trace Creek. This shows a median pH of 4.6 and an average of 4.7 SU.

Table 1: Summary statistics of precipitation pH at NADP/NTN Monitoring Location MO05, University Forest, Butler County, MO 1992-2003. (407 samples)

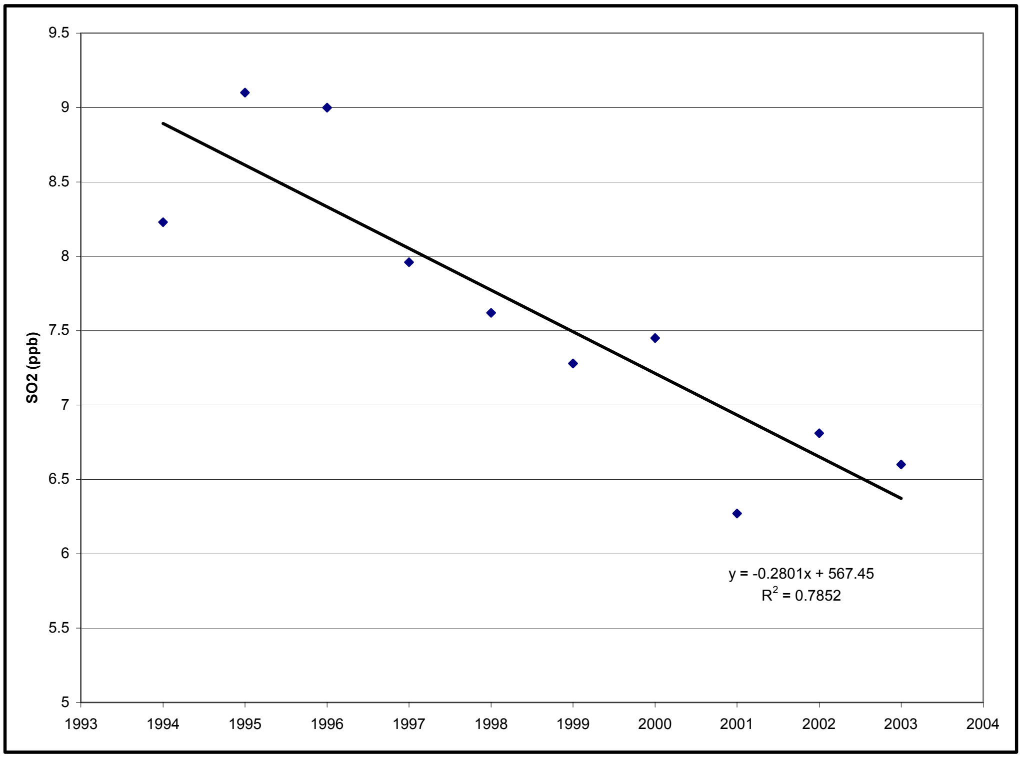
	pH (SU)
Minimum	3.69
1st quartile	4.45
Median	4.64
3rd quartile	4.89
Maximum	7.95
Mean	4.74

Source: National Atmospheric Deposition Program

The primary anthropogenic source of acid rain is sulfur dioxide, of which Doe Run's Glover Smelter was the principle source in the vicinity of Trace Creek. The smelter is located about 16 miles west of the headwater area of Trace Creek. It ceased operation in December 2003 and it is possible that this event may help to mitigate the acid rain problem. Over the last ten years of operation, there has been a steady decline in the annual average of sulfur dioxide detected from this facility (Figure 2).

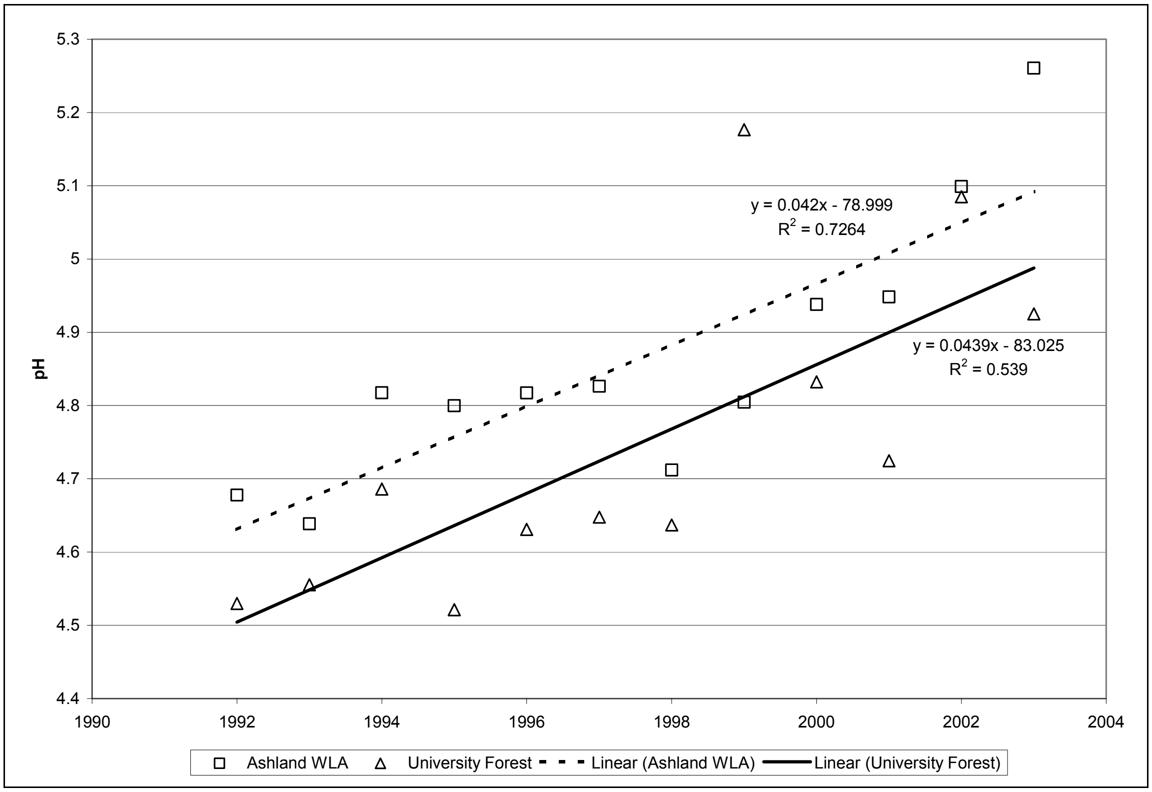
Sulfur dioxide emissions are produced primarily through the sintering process, in which sulfur compounds are separated from the lead containing minerals with a blast of hot air. The Glover Smelter was constructed prior to the federal Clean Air Act, and therefore was not required to obtain an air pollution construction permit or to control emissions of sulfur dioxide (Rustige, 2004).

Figure 2: Average annual ambient detection of sulfur dioxide near Glover Smelter



Over the last ten years, there has been a trend toward more neutral pH in the precipitation measured at University Forest. This is consistent with the nationwide trend of generally reduced acidity in precipitation that is attributed to reduced sulfur dioxide emissions (Nilles 2003). Figure 2 shows a comparison of the trend at University Forest with that of the Ashland Wildlife Area, located 120 miles to the northwest of the smelter. The Ashland Wildlife Area, usually upwind from the Glover facility, has for the most part had slightly higher pH in its precipitation. A more detailed analysis comparing the local rainfall acidity with background acidity is in Appendix D.

Figure 3: Trends in average annual precipitation pH at University Forest and Ashland Wildlife Area



Buffering Capacity

Another potential source for natural acidity in the stream is the rock that underlies it and the soil adjacent to it. In most Missouri streams, acidic rain is quickly buffered by the calcium carbonate that abounds in surface limestone in stream bottoms and within watersheds. As a result, stream water in most of the State is generally neutral or slightly alkaline. However, Trace Creek is located in the St. Francois Mountains, where the prevailing geology includes a relatively small proportion of limestone. Surface geological formations in the headwater area of Trace Creek include undivided residuum and outcrops of the St Francois Mountains Volcanic Supergroup, consisting mainly of rhyolite and albic rhyolite (Thompson, 1995).

In the undivided residuum areas, the parent material is uncertain; however, much of it has been leached of carbonate materials, leaving a conglomerate of chert, sandstone, and unconsolidated clays (Pratt et al., 1992). Rhyolite and albic rhyolite are silicate based rock types that do not provide buffering capacity to acidic solutions. In this environment, streams' capacity to neutralize acidity is reduced, particularly in headwater areas. (Winter et al, 2002).

Downstream from the headwater area, the Davis formation underlies the surface. It consists of interbedded green shale, sandy and silty dolomite, and calcareous siltstone (Pratt et al., 1992). In the area of the impaired segment, and further downstream, Trace Creek flows through a narrow

flood plain of soil with acidic characteristics. This area has been mapped Tilk very gravelly sandy loam. The Tilk series is a loamy-skeletal, siliceous, active, mesic Ultic Hapludalf. Its reaction ranges from strongly acid to slightly acid in the surface horizon, and very strongly acid to moderately acid in the subsurface. (USDA-NRCS, 2004).

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Targets

Designated Uses:
The designated uses of Trace Creek, WBID 2850, are:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption

The use that is impaired is Protection of Warm Water Aquatic Life. The stream classifications and designated uses may be found at 10 CSR 20-7.031(1)(C) and Table G.

Anti-degradation Policy:
Missouri's Water Quality Standards include the Environmental Protection Agency (EPA) "three-tiered" approach to anti-degradation, and may be found at 10 CSR 20-7.031(2).

Tier I defines baseline conditions for all waters and requires that existing beneficial uses be protected. TMDLs would normally be based on this tier when waters are impacted by pollutants originating before the enactment of the Clean Water Law, assuring that numeric criteria (such as dissolved oxygen and ammonia) are met to protect uses.

Tier II requires that no degradation of high-quality waters occur unless limited lowering of quality is shown to be necessary for "economic and social development." In absence of socioeconomic justification for lowered water quality, TMDLs must be based on maintaining existing water quality.

Tier III (the most stringent tier) applies to waters designated in the water quality standards as outstanding state and national resource waters; Tier III requires that no degradation under any conditions occurs. Management may prohibit discharge or certain polluting activities. TMDLs would need to assure no measurable increase in pollutant loading.

This TMDL will result in the protection of existing water quality, which conforms to Missouri's Tier II anti-degradation policy.

Specific Criteria:
Missouri's Water Quality Standards (WQS), 10 CSR 20-7.031(4)(E), state that water contaminants shall not cause pH to be outside of the range of 6.5-9.0 Standard Units (SU)

3. Calculation of Load Capacity

Load capacity (LC) is defined as the greatest amount of a pollutant a waterbody can assimilate without being in violation of Missouri's Water Quality Standards. This total load is then divided among a Waste Load Allocation (WLA) for point sources, a Load Allocation (LA) for nonpoint sources and a margin of safety (MOS). Unlike other pollutants, pH is not a load in the conventional sense. Rather, it is a measure of the acidity or alkalinity of a solution (Webnox. 2003). More precisely, it is defined as the negative logarithm (base 10) of the hydrogen ion concentration in solution. This is how the Standard Units (SU) of pH are derived. A solution with a neutral pH of 7 has a concentration of 10^{-7} gram-atoms of hydrogen ions per liter, and is one tenth as acidic as a solution with a pH of 6, that has a concentration of 10^{-6} gram atoms of hydrogen ions per liter.

Hydrogen ions are a very changeable component of water quality. When introduced to a solution with common buffers such as calcium carbonate, they react quickly to produce carbonic acid, which then degrades to produce water and carbon dioxide.

Therefore, rather than a mass-per-unit time measure, this TMDL uses a different appropriate measure, as allowed by 40 CFR §130.2(i). In this case, it is the Missouri state water quality criteria of a range between 6.5 and 9 SU.

4. Load Allocation (Nonpoint Source Load)

Load Allocation (LA) is the maximum allowable amount of the pollutant that can be assigned to nonpoint sources. In consideration of the local geology, soil and precipitation characteristics, it is evident that land use management within the watershed will have a limited impact in controlling acidity in the stream. Application of lime on crops and pasture lands may help mitigate stream acidity on a temporary basis, but such amendment is economically unfeasible and it would affect a relatively small portion of the watershed.

The principal nonpoint source of acidity is unbuffered acid rain that is partially attributable to sulfur dioxide emissions from the Glover Smelter. Background atmospheric contributions include sulfur dioxide drifting from more distant sources as well as the natural production of carbonic acid from carbon dioxide. The Glover Smelter halted operations in December 2003 for economic reasons. Previously, it was emitting SO_x (all types of sulfur oxides) at rates between 20,000 and 50,000 tons per year. These rates are high, but because this is an older facility there were no real controls on SO_x emissions.

The LA for this TMDL prescribes that runoff will achieve a pH of 6.5 to 9. The Glover Smelter shutdown and unspecified reductions in sulfur dioxide air emissions may have already resulted in this LA. Future monitoring will track the goal.

5. Waste Load Allocation (Point Source Loads)

The Wasteload Allocation (WLA) is the maximum allowable amount of the pollutant that can be assigned to point sources. As already stated, the only point source within the watershed upstream

from the impaired segment is the sawmill operated by the Madison County Wood Products Company (MCWP). Currently, the facility has a stormwater permit (MO-R22A120), which is applicable for primary lumber and wood products operations. This general permit requires that runoff from the facility meet all applicable water quality standards, both general and specific. The water quality standard that applies to pH is, as stated before, 6.5-9.0 SU. The permit also requires maintenance of a Stormwater Pollution Prevention Plan (SWPPP) that addresses all stormwater discharges from the site and lists the Best Management Practices (BMPs) that are used to control storm water runoff.

6. Margin of Safety (MOS)

The margin of safety is used to account for uncertainty concerning the relationship between pollutant load and instream water quality. For this TMDL, site inspections and monitoring by the department will ascertain whether MCWP is meeting the terms of its SWPPP. Additionally, any new discharger that may locate in the watershed will have to meet the pH water quality standard at end of pipe.

Further, Glover Smelter closed December 2003, as previously stated. If the Doe Run Corporation decides to resume operations, the smelter will need to have more stringent air emission limits than it had historically. This will help to ensure protection of water quality as well as air quality in the watershed.

7. Seasonal Variation

While it is acknowledged that the pH of any given water sample varies with temperature, the WQS of 6.5 - 9.0 SU applies year-round.

8. Monitoring Plans for TMDL under the Phased Approach

Fiscal year 2005 quality assurance project plan (FY05 QAPP) calls for monitoring twice a year in Trace Creek at sites #1, #2, and #4 in Table 2 (see also map in Appendix B-1). The parameters include pH, Alkalinity, Acidity, Temperature, Dissolved Oxygen, Sulfate, Specific Conductivity, and a suite of others less relevant to this TMDL.

Table 2: Sampling Site Locations

#	Site ID	WBID	Latitude	Longitude	Description
1	2850/5.4	2850	37.4343	-90.4013977	Trace Creek 0.1 mile above Sawmill Tributary
2	2850/5.3/0.1	2850	37.4319	-90.4001007	Sawmill Tributary 0.1 mile above mouth
3	2850/5.2	2850	37.4313	-90.4004974	Trace Creek just below Sawmill Tributary
4	2850/4.2	2850	37.4166	-90.4009018	Trace Creek 1.1 mile below Sawmill trib.
5	2850/2.6/0.1	2850	37.3976	-90.4123993	Trib. to Trace Creek 2.5 mile below Sawmill Trib.
6	2850/2.0	2850	37.3905	-90.4164963	Trace Creek 3.1 mile below Sawmill Tributary

9. Implementation

The acidity of the local precipitation and the flood plain soils are indicative that much of the acidity in Trace Creek is due to factors that are beyond the control of the only point source discharger in the watershed, Madison County Wood Products Company. There are also no readily identifiable practices that would mitigate the nonpoint sources of acidity. The current data set is not data rich, but indicates no impairment from pH according to 2003-2004 data. Monitoring pH at the existing sites (Table 2) should provide sufficient data to determine whether this is a permanent or a temporary condition.

If operations resume at the Glover Smelter, air quality modeling will be necessary to demonstrate compliance with the National Ambient Air Quality Standard for sulfur dioxide (SO_2). To meet the standard, SO_2 emissions will likely need to be reduced from historic emission rates. These emission reductions, in turn, will help to protect Trace Creek and other streams in the St. Francois Mountains from the effects of acid rain. Continued improvements in air quality through SO_2 control are likely to improve pH values in Trace Creek.

All Missouri TMDLs are phased. If future monitoring reports reveal that water quality standards are not being met, this TMDL will be re-opened and re-evaluated.

10. Reasonable Assurances

The department has the authority to write and enforce Missouri State Operating Permits, which should provide reasonable assurance that instream water quality standards will be met. Should the Glover Smelter resume operation after December 1, 2008 (five years from shut-down), the department's Air Pollution Control Program will have the authority to write and enforce permits establishing more stringent SO_2 emission limits. Compliance with such limits enforced through monitoring and monthly reports should provide reasonable assurance that air quality will improve with a corresponding improvement in water quality. Parallel changes in 10 CSR 10-6.260 *Restriction of Emission of Sulfur Compounds*, which establishes specific SO_2 emission limits, will also be necessary. If Glover Smelter resumes operation prior to December 1, 2008, they must comply with 10 CSR 10-6.260. The regulation prohibits SOx (all types of sulfur compounds) sources from causing or contributing to violations of the National Ambient Air Quality Standard, which will need to be demonstrated through an air quality modeling study prior to start-up.

11. Public Participation

This water quality limited segment is included on the approved 2002 303(d) list for Missouri. The Missouri Department of Natural Resources, Water Protection Program, developed this TMDL. The public notice period was from July 30 to August 29, 2004. Groups that received the public notice announcement included the Missouri Clean Water Commission, the Water Quality Coordinating Committee, the TMDL Policy Advisory Committee, Stream Team volunteers in the watershed (12), the appropriate legislators (2), Madison County Wood Products Company, the Doe Run Company and others that routinely receive the public notice of Missouri State Operating Permits. A copy of the notice, any comments received and the department responses have been placed in the Trace Creek file.

12. Appendices and List of Documents on File with DNR

Appendix A – Land Use Types for the Trace Creek Watershed
Appendix B – Maps of Sample Locations and Impaired Stream Segment
Appendix C – Water Quality Data
Appendix D – Comparative analysis of acid precipitation

Documents on File

Madison County Wood Products Company, Permit #MO-R22A120

Precipitation and pH data from the National Atmospheric Deposition Program, National Trends Network, collected at the University Forest monitoring station and the Ashland Wildlife Area in Missouri

Public Notice comments and responses

Trace Creek Information Sheet

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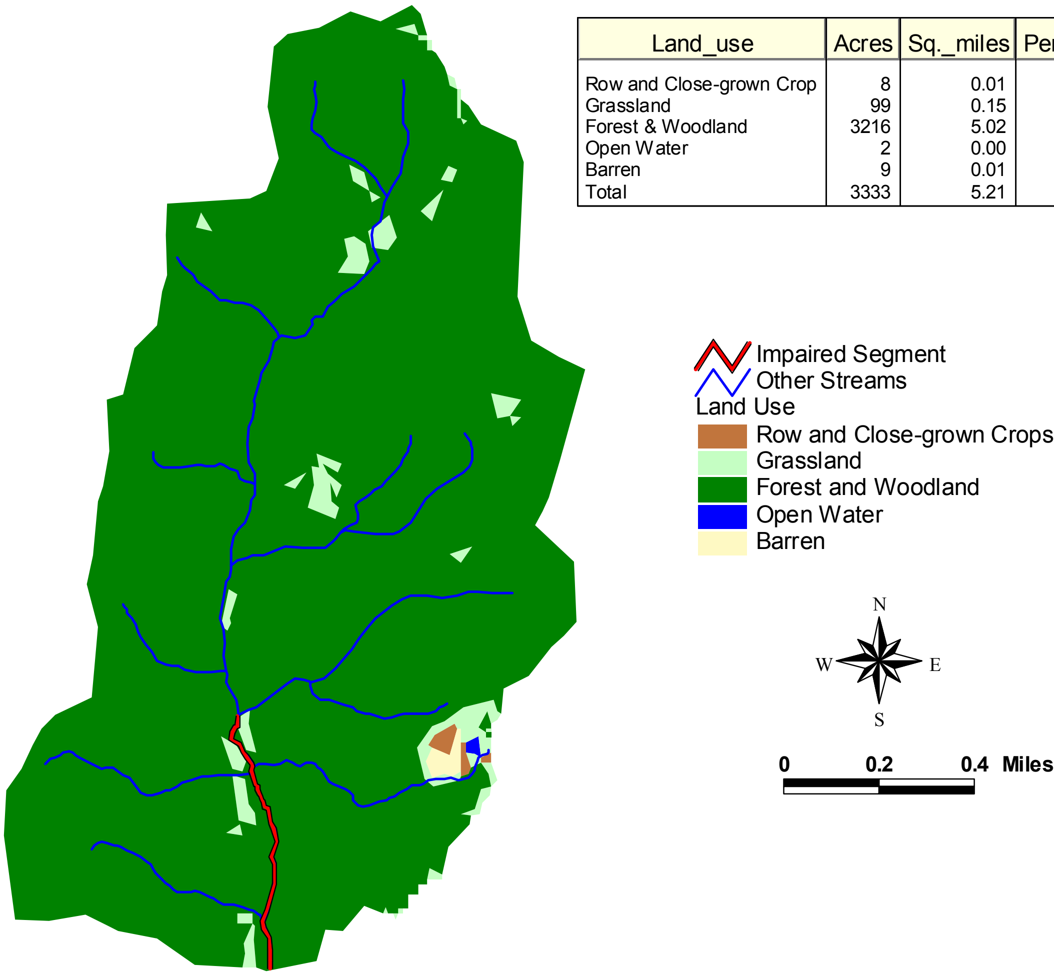
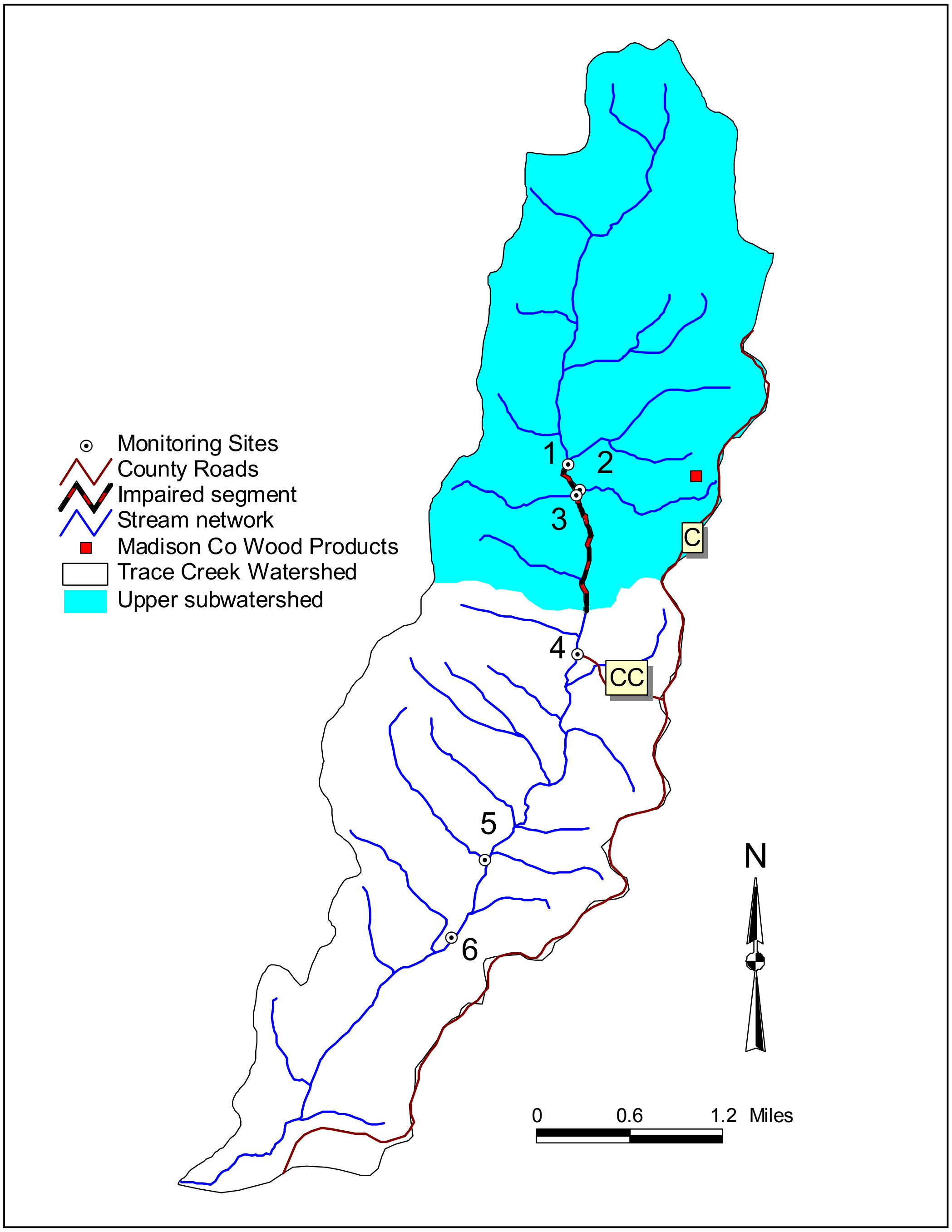
Appendix A
Land Use Map for Trace Creek



Land_use	Acres	Sq._miles	Percentage
Row and Close-grown Crop	8	0.01	0.2
Grassland	99	0.15	3.0
Forest & Woodland	3216	5.02	96.5
Open Water	2	0.00	0.1
Barren	9	0.01	0.3
Total	3333	5.21	100.0

Appendix B-1
Location of Monitoring Sites and Impaired Stream Segment in Trace Creek Watershed

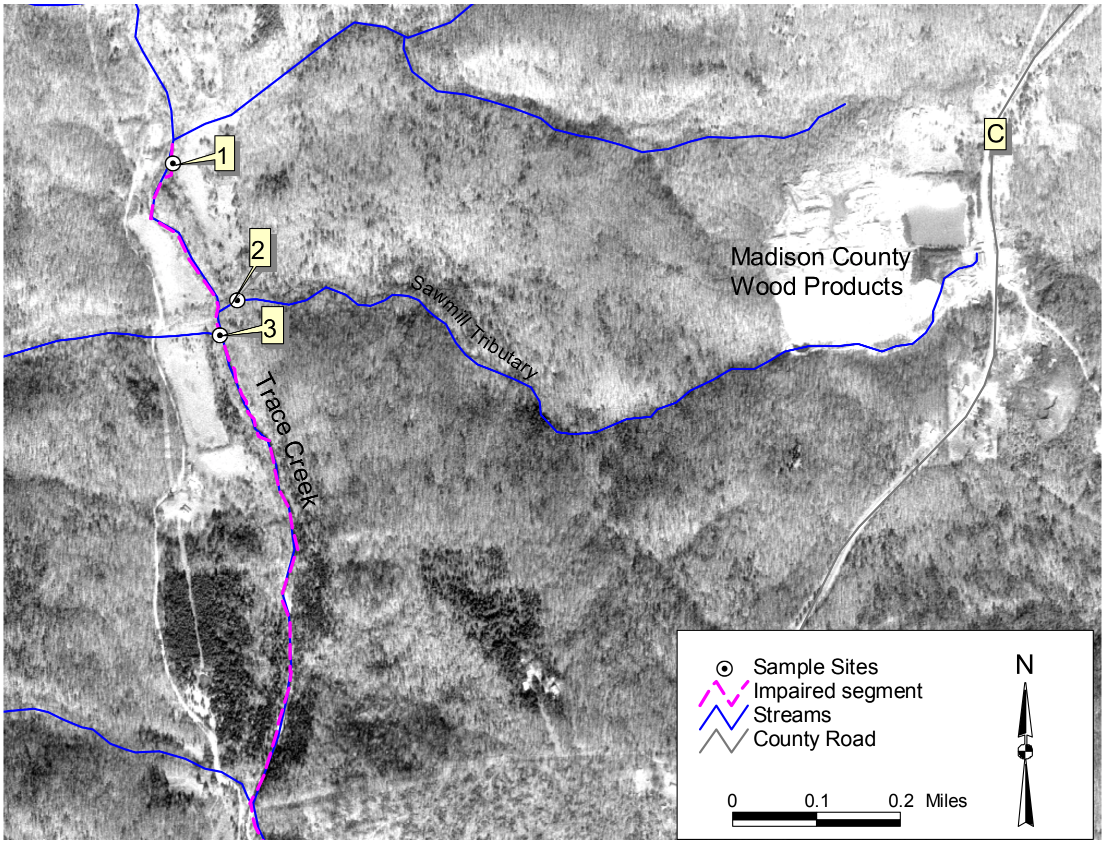


Site Index

1 – Trace Creek 0.1 mile above Sawmill Tributary
2 – Sawmill Tributary 0.1 mile above mouth
3 – Trace Creek just below Sawmill Tributary
4 – Trace Creek 1.1 miles below Sawmill Tributary
5 – Tributary to Trace Creek 2.5 miles below Sawmill Tributary
6 – Trace Creek 3.1 miles below Sawmill Tributary

Appendix B-2
Landscape of the area around Madison County Wood Products

Key for sampling sites on page 14



Appendix C
Water Quality Data

(Complete results for 8/19/04 data not yet available)

Site #	Site ID	Site Name	Date	Flow (cfs)	Temp (^{o}C)	pH	SC (mmho/cm)	Alk (mg/L)
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	3/4/1993		4	5.8		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	3/17/1993	2	6	4.5	42	
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	7/15/1995			7.9	76	67
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	4/6/2000	1		6.6	48	
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	4/16/2000			6.6		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	4/25/2000			6.4		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	4/30/2000			6.4		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	5/14/2000			6.4		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	5/18/2000	0.1	15	6.4	66	
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	6/11/2000			6.2		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	6/18/2000			6.1		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	7/2/2000			6.3		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	7/24/2000			6.2		
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	7/15/2003	0.12	19	6.7	64	25
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	5/17/2004	3	16	6.7	62	15
1	2850/5.4	Trace Cr 0.1 mi above Sawmill trib	8/19/2004	0.03	18	6.6	75	
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	3/4/1993		4	3.8		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	3/17/1993	0.4	5	4.0	220	
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	7/15/1995			4.1	425	539
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	4/6/2000	0.1	20	7.4	174	
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	4/16/2000			6.9		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	4/25/2000			6.7		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	4/30/2000			6.5		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	5/14/2000			6.5		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	5/18/2000	0.01	17	6.4	168	
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	6/11/2000			6.4		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	7/2/2000			6.8		
2	2850/5.3/0.1	Sawmill trib 0.1 mi above mouth	7/24/2000			6.4		
3	2850/5.2	Trace Cr just below Sawmill trib	3/4/1993		4	4.1		
3	2850/5.2	Trace Cr just below Sawmill trib	3/17/1993	2.4	6	4.1	59	
3	2850/5.2	Trace Cr just below Sawmill trib	7/15/1995			6.5	116	69
3	2850/5.2	Trace Cr just below Sawmill trib	7/15/2003	0.12	21	7.1	128	58
3	2850/5.2	Trace Cr just below Sawmill trib	8/19/2004	0.1		7.5	162	
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	3/17/1993		7	4.7	72	
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	7/15/1995			7.1	164	120
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	4/6/2000	1.5	17	7.3	94	
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	4/16/2000			7.5		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	4/25/2000			7.2		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	4/30/2000	4.5		7.5		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	5/14/2000	2		7.5		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	5/18/2000	0.2	19	7.1	167	
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	6/11/2000			7.3		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	6/18/2000			6.8		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	7/2/2000			7.3		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	7/24/2000			7.2		
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	7/15/2003	0.03	23.5	7.35	200	107
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	5/17/2004	3.8	20	7.2	120	30
4	2850/4.2	Trace Cr 1.1 mi below Sawmill trib	8/19/2004	0.1	20	7.1	228	
5	2850/2.6/0.1	Trib to Trace Cr 2.5 mi below Sawmill trib	3/17/1993	0.35	8	5.9	120	
5	2850/2.6/0.1	Trib to Trace Cr 2.5 mi below Sawmill trib	5/17/2004	0.15	20	7.5	253	70
6	2850/2.0	Trace Cr 3.1 mi below Sawmill trib	3/17/1993		6	5.4	92	

Flow (cfs) = cubic feet per second; Temp (^{o}C)= Temperature in degrees Celsius; SC (mmho/cm) = Specific Conductivity in millimhos per centimeter; Alk (mg/L) = Alkalinity in milligrams per liter (or parts per million)

Appendix D
Comparative analysis of acid precipitation

The central question concerning the source of rainfall acidity is whether it is primarily due to sulfur dioxide emissions from the Glover Smelter, or more because of background factors. Therefore, a comparison was made between the precipitation data for the University Forest Station and a reference station, the Ashland Wildlife Area in Boone County. Staff examined and compared weekly precipitation pH data from 1991 to 2003.

Figure D-1: Location of the Monitoring Stations

There are two assumptions in this comparison. One is that, for those weeks in which there are data for the University Forest station and the Ashland station, the precipitation is from events occurring in similar general weather patterns. The other is that the Ashland station is usually upwind from the Glover Smelter, and during the relatively infrequent times that the wind is from the east, it is at sufficient distance that precipitation acidity resulting from smelter emissions would be dispersed.

Weekly pH readings for the University Forest monitoring station were subtracted from readings for the same week at Ashland. A positive result indicated greater acidity at the University Forest station, and a negative result indicated the opposite. Tied readings were counted as zero and

discarded. The large sample size made it possible to use a large sample approximation to modify the data set to a normal distribution. The probability of results were derived as follows (Helsel and Hirsch, 2002):

$$Z^{+} = [S^{+} - \tfrac{1}{2} - \mu_{S+}] / \sigma_{S+}$$

where

Z^{+} = Number of standard deviations above 0 in a normal distribution
S^{+} = Number of positive results
n = Number of comparisons
μ_{S+} = n/2
$\sigma_{S+} = \tfrac{1}{2}\sqrt{n}$

Results were as follows:

pH comparison	Ashland Wildlife Area – University Forest
n	267
S^{+}	150
μ_{S+}	133.5
σ_{S+}	8.17
Z^{+}	1.96

Note: The data used in this comparison are not included in this document, but are on file with the department and are available on request.

The null hypothesis is that there is no significant difference in the pH of precipitation between what is monitored at the University Forest station and at Ashland. The probability for the null hypothesis in this case is 0.025 (Adams, 2003). Therefore, at $\alpha = 0.05$, the null hypothesis is rejected.